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THE EFFECT OF TOOLS AND SURFACES ON GRASP USED BY CHILDREN AGED 23 MONTHS

By

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A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled THE EFFECT OF TOOLS AND SURFACES ON GRASP USED BY CHILDREN AGED 23 MONTHS submitted by Janet Elaine Yakimishyn in partial fulfillment of the requirements for the degree of Master of Science.

Dedication

This thesis is dedicated to my husband, Shawn,
for his loving support and assistance.

Abstract

Pencil grasp development follows a general developmental pattern with the mature grasp being a dynamic tripod grasp or a variation. A sample of 51 children aged 23 months was drawn to assess how the drawing tool and the drawing surface affect pencil grasp. The children used three different drawing tools: a piece of a regular sized crayon, a primary marker, and a colored pencil, on a table and then a tabletop easel. The marker and the colored pencil were presented in three different orientations, counterbalanced across participants. The process was videotaped and scored using an adapted version of the five point rating system developed by Schneck & Henderson (1990). Results indicate that a short drawing tool (piece of a regular sized crayon) and an upright surface facilitate a more mature grasp.

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Introduction and Literature Review

Pencil grasp development has been extensively discussed in theoretical and empirical occupational therapy literature. Studies describe pencil grasp from that of a one-year-old through to a mature adult grasp (e.g., Bergmann, 1990; Blöte & van der Heijden, 1988; Blöte & van Gool, 1989; Blöte & Van Haasteren, 1989; Blöte, Zeilstra, & Zoetewey, 1987; Burton & Dancisak, 2000; Goodgold, 1983; Readdick, 1994; Rosenbloom & Horton, 1971; Saida & Miyashita, 1979; Schneck & Henderson, 1990; Tseng, 1998). However, few of these studies (e.g., Burton & Dancisak, 2000; Readdick, 1994) have examined how the type of writing or drawing tool affects grasp patterns. Various sources addressing interventions for preschoolers with fine motor difficulties suggest that the use of special writing tools and adapted writing environments influence the development of pencil grasp (Benbow, Hanft, & Marsh, 1992; Myers, 1992). Empirical support for the effect of special writing tools and adapted environments on early writers is lacking.

The development of pencil grasp may be understood in terms of dynamic systems theory. In this theory, development is seen as a dynamic system where behavior patterns have many component parts or subsystems which act together within the constraints of the environment and the task (Thelen, 1995). The system is self-organizing, as the behavior pattern will reflect the interaction of the many subsystems of the organism (i.e., the musculoskeletal system, the central nervous system(CNS)) with the environment and the task (Kamm, Thelen, & Jensen, 1990). As the components change, the stability of the system may be disrupted and new behavior patterns may emerge (Thelen, 1995). The behavior pattern that emerges for a particular task in a particular environment will be preferred because it requires the least amount of energy and is most efficient (Kamm, Thelen, & Jensen, 1990). This is also referred to as the attractor state (Thelen, 1995). Behavior change may also be restricted by any of the subsystems (Darrah, & Bartlett, 1995). That is, characteristics of the child, the environment or the task may limit or constrain behavior change. The organismic constraints include the neurological, physical or psychosocial

characteristics of the child. The environmental constraints are the non-organismic components to the system that are not task specific (i.e., social, physical and cultural elements). The task constraints are the limitations imposed by the nature of the task (i.e., tool used). Thus, certain behavior patterns may be elicited by altering the task or the environment (Kamm, Thelen, & Jensen, 1990; Mathiowetz & Haugen, 1994; Newell, 1986).

To apply dynamic systems theory to pencil grasp development, the typical progression of pencil grasp must first be understood. Several researchers describe four general grasp patterns demonstrated by 3 to 6 year olds: a fisted or supinate posture (primitive), a pronate or transitional posture, a static tripod, and a dynamic tripod (Readdick, 1994; Rosenbloom & Horton, 1971; Saida & Miyashita, 1979). Saida and Miyashita (1979) classified pencil grasps into four stages; primitive, transitional, static tripod and dynamic tripod. Schneck and Henderson (1990) expanded on the general grasp stages by describing 10 specific grasp patterns: 5 primitive grasps, 3 transitional grasps and 2 mature grasps. In her study, Tseng (1998) added 3 primitive grasps to those described by Schneck and Henderson, and also included another mature grasp for a total of 14 grasp patterns (see Appendix A). Thus, the grasps observed in these studies would be the typical attractor states for the children determined by the organismic (e.g., musculoskeletal system, CNS), environmental (e.g., gravity) and task (e.g., pencil size) constraints of the system.

Of most interest to the current study are the typical attractor states of children ages 1 to 4 as described by the literature (see Table 1). The results of these studies can help derive an estimate of the age at which a mature tripod grasp is typically developed. Presumably, the mature pencil grasps would be the most rigid attractor states (most efficient and require the least amount of energy) as these remain as the dominant grasp patterns from kindergarten to adulthood (Bergmann, 1990; Rosenbloom, & Horton,1971; Saida & Miyashita,1979; Schneck & Henderson, 1990; Tseng, 1998). A behavior that is

very stable or rigid cannot evolve into new forms of the behavior or adapt as readily to environmental or task constraints (Vereijken & Thelen, 1996).

In studies by Schneck and Henderson (1990) and Tseng (1998), almost half of the children aged 36-42 months had developed a mature pencil grasp. Roughly 70% of the children aged 30-35 months have not developed a mature grasp (Tseng, 1998). Available assessment tools can also provide estimates for maturity of grasp used. The Erhardt Developmental Prehension Assessment (Erhardt, 1994) places the pronate grasp at 2 to 3 years and the static tripod grasp at 3 ½ to 4 years. The Peabody Developmental Motor Scales (Folio & Fewell, 2000) places the pronate grasp between 15 and 16 months. These assessment tools imply that 2 years is a reasonable age to expect a pronate grasp, and that many children will use a mature grasp in some situations by the age of four.

Table 1

Summary of literature on pencil grasp development between 24 and 42 months

Study	Youngest Age range (in months)	Number of subjects	Primitive grasp use	Pronate grasp use	Mature grasp use
Saida & Miyashita (1979)	24	3	66.7%	33.3%	0%
Readdick (1994)	24-31	6	Did not report results based on age		
Rosenbloom & Horton (1971)	18-42	28	21.4%	78.6%	0%
Tseng (1998)	30-35	33	51.5%	18.2%	30.3%
	36-42	43	18.6%	32.6%	48.8%
Schneck & Henderson (1990)	36-42	40	35%	22.5%	47.5%

With the development of pencil grasp, there would seem to be more than one very stable attractor state or more than one mature pencil grasp, which may or may not be equally functional Schneck and Henderson (1990) found that more than 50% of their 5 to 5 years 5 months old participants used a dynamic tripod grasp, a mature grasp. Similarly, Saida and Miyashita (1979)

found that more than 50% of the children in their Japanese study used a dynamic tripod grasp by 5 years 5 months. More than 50% of participants in a British study were using a tripod posture at 6 years (Rosenbloom & Horton, 1971). Some authors see the dynamic tripod as the desired mature grasp (Benbow, Hanft & Marsh, 1992).

The lateral tripod grasp is also described in the literature. Due to its high incidence in some studies, the lateral tripod grasp is viewed as an alternative mature grasp (Bergmann, 1990; Tseng, 1998; Ziviani, 1995). Tseng (1998) found that up to 44% of the older children in her study used a lateral tripod grasp. In fact, Taiwanese children in her study demonstrated a much higher percentage (over 40%) of lateral tripod grasp in children ages 5 years 5 months to 5 years 9 months and 6 years to 6 years 4 months (Tseng, 1998) than a sample of American children of the same age (approximately 25%; Schneck & Henderson, 1990). However, there is some debate as to its equality to the dynamic tripod. Benbow (1995) speculated that children develop a lateral tripod grasp as their mature grasp because their intrinsic hand muscles are not yet ready to provide the stability needed for delicate manipulations of the dynamic tripod. The lateral tripod provides the stability needed by using extrinsic hand muscles, at the expense of mobility. Although this grasp is commonly seen in adults, the long-term effects in terms of fatigue and pain have not been determined (Ziviani, 1995). The desired mature pencil grasp may be the dynamic tripod, but there is evidence that the lateral tripod grasp may be equally functional.

A third mature grasp, the quadrupod grasp, is only mentioned in Tseng's (1998) study. This grasp is similar to the dynamic tripod, but with four rather than three fingers holding the pencil (see Appendix B for description). She reported that 30.2% of children in the youngest age range (3 years 0 months to 3 years 5 months) used the quadrupod grasp and 18.6% used a dynamic or a lateral tripod grasp. Looking at children in the oldest age range (6 years 0 months to 6 years 5 months), Tseng found that only 8.0% of those in her sample used a quadrupod grasp and 88.0% used either the dynamic tripod or

the lateral tripod. Thus, while use of the lateral and dynamic tripod grasps increases with age, the use of the quadrupod grasp declines. These results suggest that this is not a commonly seen mature pencil grasp.

The point where a child is ready to acquire a mature pencil grasp is partly dependent upon inherent characteristics of the individual such as age and gender (Blöte & Van Haasteren, 1989). As noted above, the age of the child is a good predictor of how a child is likely to hold a pencil (Goodgold, 1983; Readdick, 1994; Rosenbloom & Horton, 1971; Saida & Miyashita, 1979; Schneck & Henderson, 1990; Tseng, 1998). Gender may also be a factor, as Saida and Miyashita (1979) found that grasp patterns were more advanced in three-year-old girls than in three-year-old boys. Other inherent characteristics such as overall rate of development may also affect the age at which a child uses a mature pencil grasp.

In addition to individual characteristics, the pre-writing environment to which the child is exposed will also influence the acquisition of a mature grasp. The size of the writing tool may dictate the grasp used. Many studies describing pencil grasp development used standard no. 2 type pencils or colored pencils as the writing tool (Blöte & Van Haasteren, 1989; Saida & Miyashita, 1979; Schneck, 1991; Tseng, 1998). However, some researchers suggest that manipulation of the writing tool may cause enough change in the environmental subsystem to influence the use of a more mature grasp. For example, Burton & Dancisak (2000) used Schneck and Henderson's (1991) five-point rating system to determine the grasp used by 3 to 5 year olds on five diameters of writing tools - 4.7 mm, 7.9 mm (standard pencil width), 11.1 mm (small marker), 14.3 mm (small marker) and 17.5 mm (large marker). They found that more mature grasps were used as the diameter of the writing tool decreased. Readdick (1994) assessed grasps used by 20 children, between 2 years to 4 years 11 months of age, in drawing with markers, pencils, and crayons. The only significant difference in grasp was between primary pencils (wider than standard pencils; M (grasp) = 2.57, SD = .65) and standard pencils (M (grasp) = 2.86, SD = .66), with the standard pencils eliciting a more mature

grasp. However, Readdick indicated that, generally, the children in her study used the same grasp regardless of the size of writing tool. These studies suggest that a smaller diameter pencil is more likely to facilitate the use of a more mature grasp pattern. Jarman (1984) stated that there is no proof that preschool children need thick pencils for control. In fact, he says that when preschoolers have a choice, they prefer thin writing tools.

Other writing tools suggested in the literature to facilitate mature grasp development are preschool crayons and small pieces of chalk (Myers, 1992). The preschool crayon is reported to provide support for the child's hand when held in an open web space posture and used on a vertical surface. The short length of the broken chalk requires the child to hold it with the tips of the thumb, index and middle fingers, precluding a fisted, whole hand or five-fingered grasp. However, no empirical studies were found assessing grasp changes when preschool crayons or pieces of chalk were used. Overall, there is some support in the literature that some writing tools will facilitate the movement from a pronate grasp to a mature pencil grasp more effectively, as suggested by dynamic systems theory, but further validation is necessary.

Another environmental adaptation that may facilitate the use of a mature pencil grasp is drawing or writing on a vertical surface. Myers (1992) suggested that vertical surfaces are important for appropriate hand and wrist position for fine motor and handwriting activities. When working on a vertical surface, the wrist is positioned in stable wrist extension which supports thumb abduction and opposition as required in a tripod grasp (Benbow, as cited in Myers, 1992; Strickland, 1995). Benbow (1990) also indicated that wrist extension seemed to facilitate balanced use of the hand's intrinsic muscles. Combining the broken chalk, which facilitates a grasp between the thumb, index and middle fingers (tripod), and the vertical surface, which encourages wrist extension, provides strong task constraints on pencil grasp. Dynamic systems theory, combined with previous literature, suggests that the use of such a task constraint would result in the reorganization of the system needed to produce a mature grasp.

There is also some indication in the literature that a minor change in the orientation of the writing tool on the table may affect the grasp used. Burton and Dancisak (2000) presented writing tools in four orientations (pointed left, right, towards and away from the child to line up with their drawing task) as they found that some children did not adjust their grasp after picking up the writing tool. However, they did not indicate if these children used a more mature grasp with any particular orientation. This small task constraint may be important when studying grasp use.

There is some evidence in the literature that environmental adaptations to encourage a more mature grasp may be successful with children as young as the age of two. Case-Smith (1995) stated that a two-year-old child has the postural stability in sitting to allow controlled use of the hand. As well, children around this age are not likely to be already using a mature pencil grasp. Previous research suggests that most of the children will still be using a primitive or pronate grasp allowing manipulation of the environment (writing tool and drawing surface angle) to prompt the use of a mature grasp. Close to 50% of three-year-olds are already using a mature tripod grasp (Schneck & Henderson, 1990; Tseng, 1998). Thus, an older sample of children may not demonstrate as much change in response to the environmental adaptations.

The literature is incomplete in the area of early pencil grasp development. Studies involving younger children provided little information about the types of grasp used before the age of 2 years. Children may start to use writing tools to mark paper as young as 10 months old (Ames, as cited in Blöte & Van Haasteren, 1989), so it is important to know how younger children handle writing tools. Myers (1992) suggested that early practice with pencils and markers may result in a poor pencil grasp, partly because the child may be using writing tools before his/her hands are ready. If a child does too much pencil work with the immature grasp, his/her pencil posture may become fixed at an intermediate level of skill. More study is necessary regarding how very young children approach available writing tools. Although many preschool writing tools are described in clinical literature, very few studies have looked at

young preschool children's pencil grasps with any tool other than a standard-sized pencil. As well, the use of a vertical writing surface is suggested in the literature (Myers, 1992), but no studies were found that evaluated this practice. The use of task constraints to move a child's grasp pattern from a less mature to a more mature grasp can be explained by introducing instability into a system and causing it to reorganize and find a new attractor state (mature grasp). A study using dynamic systems theory to analyze early pencil grasp development will be a valuable contribution to the occupational therapy literature.

The current study looked at how the drawing tool and the drawing surface affected the pencil grasp of young children. The literature suggests that children will use a more mature pencil grasp with a thinner writing tool. Changes in writing surface from horizontal to vertical may produce a more mature grasp. Dynamic systems theory suggests that the introduction of these task constraints will introduce instability into the system, and the child may use a more mature grasp as a result. The study addressed the following research hypotheses:

1. Children will use a more mature grasp when using a colored pencil compared to a thick marker.
2. Children will use a more mature grasp when using a short piece of crayon compared to a long colored pencil.
3. Children will use a more mature grasp when drawing on the vertical surface compared to the horizontal surface.

Method

Sample

Participants. Children for the pencil grasp study were drawn from the convenience sample of a longitudinal study that followed 120 children from ages 9 to 23 months (the Baby study). The Baby Study sample was recruited from public health clinics, birth records of a major hospital, day cares, newspaper advertisements, and personal contacts. Children who were born pre-term, who had health concerns at birth, or whose parents had any developmental or health concerns about their child at 9 months of age were excluded from the sample at the time of recruitment. Only children whose parents spoke English to them were included.

The investigators from the Baby Study sent a letter to 76 of the participating families asking if they are willing to be contacted by the principal investigator. A letter describing the current study was attached (see appendixes A, B and C) along with a stamped self-addressed response card on which parents indicated their interest or lack of interest in the Pencil Grasp Study. The principal investigator did not have access to names and phone numbers until the parents gave permission for that information to be released.

Of the 63 families who agreed to have their child participate, 7 children refused to participate at some point in the assessment, 2 completed the easel task standing thus changing the surface angle, 1 child did not draw or scribble but banged on the paper with all the tools and 2 assessments had video difficulties. Of the 7 children who refused to participate, 5 were boys and 2 were girls. The parents of all but one of these 7 children indicated that their child enjoyed this type of task. A number of parents commented that their child was tired or not feeling well, which would explain their reluctance to participate. All of them had just been through a 30-minute assessment. There is no indication from the information gathered that these 7 children would have had more difficulty with the task than the children who did participate.

The number of children in the final sample was 51 (22 females and 29 males) with a mean age of 23 months and 11 days (range 23 months, 0 days to

23 months 29 days). During the assessment, 25 of the 51 children used their right hand for all 14 presentations, 23 used their right hand for 1 to 13 of the presentations and their left hand for the rest of the presentations (mixed hand use) and 3 used only their left hand. In the mixed hand group, the children tended to use their right hand more than their left (M = 9.3 out of 14 presentations). All participants had typical development as determined using the DISC Preschool Screen (DPS; Parker, Mainland, & Amdur, 1997). Ninety percent of the parents in the Pencil Grasp Study classified themselves as White and 10% as other than Black, Chinese or South Asian. When recruited initially, 88% of the fathers and 36% of the mothers worked 30 hours or more per week. For most (81%) of the sample, the average annual family income was $40,000 (Canadian) or higher. The average educational level for the mothers was 15.7 years with 47% completing a college/university degree and16% completing a graduate degree. The average educational level for the fathers was 17.7 years with 47% completing a college/university degree and 12% completing a graduate degree.

Research Design

Research Variables. There are two independent variables. These are writing tool (preschool crayon, primary marker, and colored pencil) and writing surface (vertical versus horizontal). The dependent variable for this study is the maturity of the pencil grasp used.

Procedure. A pilot study was done with two 23-month-old children and three 26-month-old children to refine the procedures. From the pilot study, it was determined that the child should be videotaped from the left and the right for optimal scoring. The presentation of the marker and pencil was altered to include three orientations (pointing left, pointing right and pointing toward the child) as two of the five children in the pilot study used a different grasp depending on how the tool was oriented on the table.

The principal investigator or designee met with the parents after their child had completed the DPS screen for the Baby study and explained the pencil grasp study prior to obtaining consent to participate (Appendixes A, B

and C). Parents were present with their child during the study. All children were tested in a quiet room. The principal investigator assessed all 51 children except for 3 children who were assessed by a trained research assistant. The three writing tools were a piece of a regular sized crayon (20.0 mm in length and 10.2 mm in diameter), a primary marker (110.0 mm in length and 16.9 mm in diameter), and a colored pencil (180.0 mm in length and 8.6 mm in diameter). A round colored pencil was chosen over a standard pencil, as this surface is similar to that of the marker and the crayon, whereas a standard pencil's hexagonal surface is not. As well, the regular pencil was not as interesting as the colored writing tool to some of the children in the pilot study. Letter-sized, office weight, white paper (8½ x 11 inches) was used. The horizontal surface was a small table at a height of 15 inches. The vertical surface was a tabletop easel placed on the table, reaching a height of 9 ½ inches above the 15-inch tabletop, with a 75° angle from horizontal. The easel had the same dimensions as one commercially available from Crayola®, but also had the same varnished wood surface as the horizontal tabletop. A tabletop easel was chosen over a standing easel because it allowed more control over the position of the child in relation to the easel (i.e. the child could not move to one side while drawing and change the angle of approach to the paper). As well, the child was supported in sitting for both the table and easel trials, keeping the testing environment as similar as possible. The chair used for all children was 7.5 inches in seat height. One video camera was set up to the left of the child and the other video camera to the right of the child; both approximately level with the table surface and including the entire height of the easel.

Each child was encouraged to draw on each surface (vertical and horizontal) using each of the three writing tools (crayon piece, colored pencil and primary marker) (See Appendix D for a detailed script). Based on the pilot study, both the markers and the colored pencils were presented in three different ways with each surface; pointing left, pointing right and pointing towards the child, for a total of 14 trials per child. As the easel did not allow enough room on the table for a pencil or marker to be placed pointing toward

the child, the pencils and markers were placed to the left or right of the easel, depending on handedness as indicated by the parents. If the parents were uncertain of handedness, it was placed to the right of the child for that surface. Only one presentation of the crayon on each surface was made, as the short length of the crayon negated any orientation effects and the task needed to be as short as possible to maintain interest. The order in which the felt marker, the colored pencil and the piece of crayon were presented was counterbalanced to control for any order effect. No significant differences in mean grasp used were found between the 6 possible orders of presentation on either surface ($F(5,45) = 0.99$, $p > .25$). The presentation of the crayon first on the table had no significant effect on the grasp subsequently used on the table with the marker or the pencil compared with presenting the crayon last (pencil: $t(33) = 0.68$, $p > .25$; marker: $t(33) = 0.89$, $p > .25$). This was calculated by comparing the mean grasps on the pencil and marker trials for children who were presented the crayon first with children who were presented the crayon last. The three orientations of the colored pencil and marker trials were not counterbalanced. The flat surface was presented before the vertical surface, as a flat surface is more familiar to most children.

Each child completed three trials each of the marker and colored pencil and one trial with the crayon on both the horizontal and the vertical surface, for a total of 14 trials per child. Any child who did not complete all 14 trials was eliminated from the study. Each trial was given only one grasp score. If the child switched hands or grasps during the trial, the most mature grasp used was scored (Saida & Miyashita, 1979). If the child switched hands during the trial but used the same grasp, the hand scored was the one the child most frequently used during the assessment.

Measures. The grasps employed by the children were coded using the categories described by Schneck and Henderson (1990; see Appendix E) and by Tseng (1998). Schneck and Henderson described 10 grasp categories using previous research and a descriptive study of 320 children aged 3 years 0 months to 6 years 11 months. For the purpose of this study, Schneck and

Henderson's categories were modified to include 4 more categories (Tseng, 1998; see Appendix F). Tseng found that 18% of children in her youngest age group (2 years 5 months to 2 years 11 months) used one of three variations of the interdigital grasp. She also described the quadrupod grasp, another mature grasp. Tseng suggested that Schneck and Henderson did not observe the interdigital grasps, as their subjects were older. As the current study used even younger children, it was necessary to include the extra grasp patterns. The actual grasp used by the children was recorded.

Further modification of Schneck and Henderson's (1990) categories were necessary to accommodate the vertical surface as the structure of the environment prevented some of the grasps from meeting all of the criteria in the rating system. For example, an adult using a mature grasp will not necessarily rest his/her forearm on the surface of the easel (see scoring for static tripod grasp in Appendix G), thus not all the requirements for this grasp were met when scoring on the easel. When forearm position is removed from the scoring criteria, wrist position and prehension were the two most salient criteria when scoring on the easel. For example, a static tripod grasp was scored by the accuracy of the prehension and the presence of wrist extension alone.

Each grasp was assigned a score from 1 to 5. Schneck (1991) developed a five point rating system from the 10 categories found in her previous research (Schneck & Henderson, 1990; see Appendix E). Tseng's (1998) four additional categories were placed on this scale for the current study for a total of 14 grasp types. Based on Tseng's presentation of the grasps in developmental order, the interdigital grasps were given a score of 2, the same score as the palmar supinate and digital pronate grasps. Accordingly, the quadrupod grasp was assigned a score of 5. However, none of the grasps with a score of 5 were used by children in this study.

Reliability. Limited information is available about the reliability of the measures. In an unpublished pilot study, Schneck 1987 (as cited in Schneck & Henderson, 1990) found the interrater reliability was .90 when using the 10 grasp categories. The five-point scale was added for Schneck's 1991 study,

though interrater reliability was not reported for that study. Urton and Dancisak (2000) assessed the utility of the 10 categories and the corresponding 5-level rating system. They found an interrater reliability of .67 for the 10 categories as measured by the proportion of perfect agreement. They did note that some individuals showed finger positions that did not match any of Schneck and Henderson's descriptions, but they were still able to categorize them based on the general characteristics of the grasp. Tseng (1998) used the modified version of Schneck and Henderson's categories, and found an interrater reliability kappa coefficient of .96. No test-retest reliability data is available on either measure.

Despite the uncertainty of the reliability of the rating system defined by Schneck (1991), with modification it appeared to be the best choice for categorization of pencil grasp. Previously used rating systems had either few, broader categories (Goodgold, 1983; Readdick, 1994; Rosenbloom & Horton, 1971; Saida & Miyashita, 1979) or extremely detailed categories that were difficult to quantify (Blöte & van der Heijden, 1988; Blöte & van Gool, 1989; Blöte & Van Haasteren, 1989; Blöte, Zeilstra & Zoetewey, 1987). The score sheet used included line drawings of the grasp so that the rater could more easily categorize the grasp.

Validity. Schneck and Henderson's rating system has good face validity. The descriptions of the grasps used were consistent with other independent studies (Blöte & van der Heijden, 1988; Blöte & Van Gool, 1989; Blöte & Van Haasteren, 1989; Blöte, Zeilstra, & Zoetewey, 1987; Goodgold, 1983; Readdick, 1994; Rosenbloom & Horton, 1971; Saida & Miyashita, 1979). Evidence for its content validity was found in a study by Urton and Dancisak (2000), who reported being able to fit all 1,200 trials from 60 participants into one of the 10 categories. Although this rating system has only been used with a flat surface, the pilot study suggested that it would capture all the grasps that may be used on a vertical surface. All the possible prehension patterns on the writing tools were described by this rating system, once the four categories described by Tseng (1998) were added.

Scoring. The mean across the three trials was used for data analysis for the table-marker, table-pencil, easel-marker and easel-pencil conditions to generate one data point for each condition for each child. Averaging was selected, as it was felt to be more representative of the child's performance than simply the lowest or highest scores of the three trials.

The grasps were scored independently from the videotape by the principal investigator. Interrater reliability was established with another trained occupational therapist using the same protocol. The second rater was trained through study of the scoring protocol, followed by scoring practice of three children with the principal investigator until a comfort level with the protocol was reached. Twenty-five percent of the grasps were then independently double-coded. Scoring was compared three times during the process to ensure there had been no observer drift, as well as to address any questions that arose. Any discrepancies in the interpretation of the protocol were discussed, and a consensus on the use of the protocol was determined for the remaining grasps to be scored. However, the original scores assigned by the principal investigator and the second rater were used to calculate the interrater reliability.

Interrater reliability from the study was calculated by correlating the double-coded grasp scores. This correlation was .88 ($p<.001$). As well, percentage agreement for these scores was 90.1%. This level of agreement indicates a moderately high level of reliability of scoring, and presumably increases the replicability of the study. To ensure that the two raters did not differ in terms of their mean ratings (i.e., that one rater was not significantly higher that the other), a t-test was performed comparing these means ($n=181$; principal investigator $M=2.641$, $SD=0.68$; second rater $M=2.635$, $SD=0.70$). This difference was not significant (effect size=0.01; $t(180)=0.22$; $p>.50$). Given these results, the scores assigned by the principal investigator were used for the double-coded participants in the analysis to preserve uniformity of scoring across all participants.

Along with the comparison of grasp scores between raters, a comparison between actual assigned grasp was done. In addition to the 18 grasps that

were scored differently between the raters, four grasps were labeled differently but resulted in the same grasp score. The percentage agreement for grasp labeling was 87.8%. Five additional grasps were initially discrepant due to recording error/rater fatigue later corrected by the rater rather than a disagreement in grasp label. They did not differ in score, and as such are not reflected in the scoring reliability. Including the recording errors, the percentage agreement was 85.1%.

Overall, the two raters had most trouble agreeing on the crayon-table, the marker-table and the pencil (table and easel) presentations (see Appendix H). A number of possible explanations exist regarding the scoring differences between the two raters. The first is that the camera angles were fixed and occasionally a child would partially obstruct the view of the hand with his or her body or scribble very briefly with the tool, making it more difficult to see the finger and wrist position. Freeze frame was useful for this but sometimes tended to make the picture blurry and thus more difficult to score. Related to this is that the principal investigator had observed, in person, all but one of the children double-scored at the time of videotaping from a different angle than on the videotapes whereas the second rater had only viewed the tapes. Another explanation is that occasionally a grasp was used that met some of the criteria for two grasps but not all the criteria for one grasp. Related to this is the occasional difference in perception of the wrist angle or prehension pattern observed between the two raters, especially with the crayon trials. As well, for the marker trials, the width of the marker and the small size of the child's finger may have made it difficult to tell if the grasp was fisted or showing some prehension. For the pencil trials, some of the children were less interested in the tool and thus grasped it loosely and used it sparingly. The crayon-table presentations were difficult to score because the length of the crayon tended to facilitate a more accurate prehension pattern but didn't affect the wrist angle, resulting in a grasp not easily captured by the grasps described in the scoring protocol. The protocol was not originally developed to be used with short

writing tools. These possible sources of rater error should be considered when planning future studies in this area.

In addition to the interrater reliability, 51% of the grasps were also double-scored by the principal investigator, resulting in an intrarater reliability of .95 (r=.95, p<.001) by correlating the scores. The percentage agreement for these scores was 95.1%. This level of agreement indicates a high level of reliability of re-scoring. To ensure that the two scorings did not differ in terms of their mean ratings (i.e., that one set of scores was not significantly higher that the other), a t-test was performed comparing these means (n=364; original score M=2.68, SD=0.77; re-score M=2.65, SD=0.77). Although this difference approached statistical significance ($t(363)$=1.64; p=.103), a very small effect size of 0.04 suggests that it is not clinically significant. The time between scorings was 3 to 5 months with the original scoring completed very close to the live videotaping. The amount of time between the live observation during the videotaping and the second scoring may account for some of the difference in the scores assigned. Only the scores originally assigned by the principal investigator were used in the analysis to ensure uniformity of scoring across all participants.

Results

The mean grasps across participants used for each condition with the standard deviation in parentheses are given in Table 2.

Table 2 Mean Grasp Used

Utensil / Surface	Marker	Pencil	Crayon
Table	2.60 (0.60)	2.56 (0.54)	2.90 (0.67)
Easel	2.68 (0.61)	2.58 (0.58)	3.59 (0.78)

The data was analyzed using repeated measures ANOVA. This analysis revealed a significant interaction effect between the utensil and surface variables ($F(1.385^{1}, 69.247) = 16.022$, $p < .001$). Though the main effects for utensil ($F(1.552, 77.612) = 52.96$, $p < .001$) and surface ($F(1,50) = 18.49$, $p < .001$) were both significant, the significant interaction rendered these main effects difficult to interpret. Thus, the data were re-analyzed using dependent t-tests. Given the increase in type I error inherent in performing seven comparisons, the significance level was Bonferroni-adjusted, from .05 to .007. There was no significant difference in grasp used between marker and pencil for either the table or the easel. As such, hypothesis 1 was not supported. However, the comparison of pencil and crayon showed a significant difference in grasp used on the easel and the table, indicating support for hypothesis 2. When comparing table and easel, there was a significant difference in the grasp used for the crayon with more mature grasps used on the easel but no significant difference for the pencil or the marker, yielding partial support for hypothesis 3. The results of the dependent t-tests are given in Table 3.

[1] The degrees of freedom are not reported as integers because sphericity was not present in the data, and as such the Greenhouse-Geisser adjustment was made to the degrees of freedom. This adjustment had no effect on the significance.

Table 3. Dependent t-test Results

Hypothesis	Comparison	t(50)	Significance	Effect size (ES)
1. Marker to pencil	Table-marker to table-pencil	0.67	>.25	.08
	Easel-marker to easel-pencil	1.72	.09	.18
2. Pencil to crayon	Table-pencil to table-crayon	3.54	.001	.57
	Easel-pencil to easel-crayon	9.21	<.001	1.48
3. Table to easel	Table-marker to easel-marker	-1.45	.15	.13
	Table-pencil to easel-pencil	-0.30	>.50	.03
	Table-crayon to easel-crayon	-4.76	<.001	.94

To determine whether the proportion of participants using mature grasps differed across the conditions, the data were collapsed into two nominal categories (immature, based on average scores of 3.5 or less and mature, scores of 3.5 or more). A score of 1, 2 or 3 includes all five of what Schneck and Henderson's (1990) describe as primitive grasps as well as the three primitive grasps added by Tseng (1998). A score of 4 or 5 includes the three transitional grasps and two mature grasps described by Schneck and Henderson as well as the additional mature grasp added by Tseng (although no grasps were scored as 5 across all participants). The differences between the primitive and transitional grasps are qualitative changes in wrist position and finger prehension where the transitional grasps are more similar to the mature grasps in these areas (extended wrist position, two or three fingers prehending with the thumb), creating two natural nominal categories. Proportions of participants using mature and immature grasps by utensil and surface are provided in Table 4. Chi-square tests were performed to clarify the effects of surface angle and writing tool on the grasp used. The McNemar chi-square test was used as the categories are not independent (Glass & Hopkins, 1996).

Table 4. Frequency (Percentage) of Immature versus Mature Grasp

Utensil / Surface	Marker		Pencil		Crayon	
	Immature	Mature	Immature	Mature	Immature	Mature
Table	94.1	5.9	98.0	2.0	82.4	17.6
Easel	90.2	9.8	94.1	5.9	23.5	76.5

The results of the chi-square tests were consistent with the dependent t-tests. Significant differences in the use of immature versus mature grasp were not found between the marker and pencil for either the table or the easel (see Table 5). There was a significant difference in the maturity of the grasp used between the pencil and crayon but only on the easel ($p<.001$), not the table ($p=.021$) when the Bonferroni correction was applied. The nonsignificant difference between the pencil and crayon when used on the table is the only difference in the results between the dependent t-tests and the chi-square tests. A significant difference in grasp used on the crayon between the table and easel was confirmed with a higher proportion of mature grasps used with the easel than with the table. Again, no significant differences were found between the table and easel conditions for the pencil or the marker. Results of the chi-square tests are given in Table 5.

Table 5 McNemar Chi-Square Test Results

Hypothesis	Comparison	p-values
1. Marker to pencil	Table-marker to table-pencil	>.50
	Easel-marker to easel-pencil	>.50
2. Pencil to crayon	Table-pencil to table-crayon	.021
	Easel-pencil to easel-crayon	<.001
3. Table to easel	Table-marker to easel-marker	>.50
	Table-pencil to easel-pencil	>.50
	Table-crayon to easel-crayon	<.001

The study also looked at the frequency of grasp used according to the 14 categories (see Appendix E). The most commonly used grasps over the study were the digital pronate grasp and the grasp with extended fingers. The total number of times that each grasp was used out of a total of 714 tool presentations (14 trials for 51 children) are presented in Table 6. The grasps used by the children during the study include 11 of the possible 14 categories. The three interdigital grasps were collapsed into one category because only one interdigital variation 3 was scored and no interdigital variation 1 grasps were scored.

Table 6. Frequency of Grasp Use

Grasp Category	Grasp Usage over study out of 714 trials	Grasp Usage on Table out of 357 trials	Grasp Usage on Easel out of 357 trials
Radial Cross Palmar	14 (2.0%)	9 (2.5%)	5 (1.4%)
Interdigital grasps	25 (3.5%)	13 (3.6%)	12 (3.4%)
Palmar Supinate	56 (7.8%)	28 (7.8%)	28 (7.8%)
Digital Pronate	227 (31.8%)	112 (31.4%)	115 (32.2%)
Brush Grasp	38 (5.3%)	34 (9.5%)	4 (1.1%)
Grasp with Extended Fingers	236 (33.1%)	124 (34.7%)	112 (31.4
Four-fingered Grasp	43 (6.0%)	13 (3.6%)	30 (8.4%)
Cross Thumb Grasp	10 (1.4%)	5 (1.4%)	5 (1.4%)
Static Tripod Grasp	65 (9.1%)	19 (5.3%)	46 (12.9%)

In addition to these results, a secondary analysis was done to look at possible gender effect due to the fact that there were fewer girls than boys who agreed to participate. A significant gender effect was found in the study ($F(1,49)=4.98$, $p= .03$) with girls (M girls = 2.97, $SD= 0.40$) scoring higher than boys (M boys = 2.70, $SD= 0.44$) with a moderate effect size of .61. There were no significant two-way interactions between gender and surface ($F=3.66$,

p=.062) or gender and utensil (F=.76, p>.25), and no three-way interaction between gender, surface and utensil (F=1.60, p=.207).

Another secondary analysis was done to look at the effects of presenting the pencil and marker in three different orientations. This procedure was not done in previous studies and the results of the current study suggest it is an important consideration. The mean grasp used on the pencil or the marker on both surfaces was categorized by the orientation of the tool when presented. The mean grasp used when the tool was presented pointing toward the child (M towards = 2.74, SD =.58) was significantly different from the mean grasp used when the tool was presented pointing to the left of the child (M left = 2.49, SD = .57) and from the mean grasp used when the tool was presented pointing to the child's right (M right = 2.58, SD =.58). The means of the left and right orientations did not differ significantly. Thus, tool orientation can have an effect on the maturity of the grasp used.

Discussion

The significant differences in grasp when comparing pencil and crayon on the easel and table provide support for the research hypothesis that children will use a more mature grasp when using a short piece of crayon compared to a long colored pencil. Although no previous studies assessed the effects of tool length on grasp use, Myers (1992) suggested that the use of a small piece of chalk on a vertical surface would facilitate a more mature grasp (a tripod grasp) in children not yet using a tripod grasp. The results of the current study support this suggestion, but also indicate that a vertical surface is more effective in producing a more mature grasp than the flat surface with a small piece of crayon. When comparing pencil to crayon on the table, the effect size was.57 versus an effect size of 1.48 when comparing pencil and crayon on the easel. Both Myers and Benbow (1990) suggested that the vertical surface is necessary to place the wrist in extension and encourage prehension in the fingers.

Dynamic systems theory can explain the behavior change observed when a piece of crayon is used on a vertical surface in this study by the task constraints it places on the musculoskeletal subsystem. Perhaps this behavior pattern is preferred because it requires the least amount of energy and is most efficient given the task constraints (Kamm, Thelen, & Jensen, 1990). The short piece of crayon requires the child to prehend the crayon with the tips of the thumb, index and middle fingers, precluding a fisted, whole hand or five-fingered grasp. The vertical surface requires wrist extension and the combined result is a more mature grasp.

The hypothesis that children will use a more mature grasp when using a colored pencil compared to a thick marker was not supported by the current study, as there was no significance difference in grasp between marker and pencil for either the table or the easel. This was inconsistent with results from Burton and Dancisak's (2000) study where more mature grasps were used with thinner writing tools rather than thicker writing tools by 3- to 5-year-olds. The results of the current study are more consistent with Readdick (1994), who

found that the 2- to 5-year-old children in her study used the same grasp regardless of the size of writing tool except for a significantly more mature grasp for thinner standard pencils compared to thicker primary pencils. A variety of explanations exist for the apparent inconsistency between current and previous results.

One explanation is that the samples from these two studies are not comparable with that of the current study. Burton and Dancisak's sample did not include any two-year-olds. Readdick included only six two-year-olds with an age range of 24 to 31 months and also included 14 three and four-year-olds. It could be that the older subjects in the other studies may be more sensitive to changes in width than the younger children in this study. Using dynamic systems theory, one would predict that older children are more likely to be in the transition state preceding mature grasp development (attractor state) and thus may be more responsive to more subtle environmental changes such as tool width. A future study using the same procedure but an older sample could test this suggestion.

A second explanation involves subtle differences between the writing tools in the three studies. Burton and Dancisak's standard pencil width was 7.9 mm and the large marker was 17.5 mm, compared to the 8.6 mm colored pencil and 16.9 mm thick marker in the current study. Readdick did not give diameters but a primary pencil is thinner than the thick marker used in the current study. It is possible that some tool widths are more optimal for facilitating mature grasps in preschool children. Burton and Dancisak's study design also differed in that they did not use actual markers or pencils but implemented barrels of various widths fitted with a ball point pen. The unfamiliarity of the writing tool and the need to hold a pen at a certain angle to get it to work may have also affected how the children in that study held the tool. As well, their study design included a drawing task in a three-sided path, whereas children with the current study drew on a blank piece of paper. The inconsistency of comparisons between marker and pencil across studies

indicates the need for further research in this area, perhaps by controlling for age and writing tool.

The final research hypothesis, that children will use a more mature grasp when drawing on the vertical surface compared to the horizontal surface, was supported by the results of this study, but only when using the crayon (ES=.94). No significant difference in grasp use between table and easel was found with either the marker or the pencil. Myers (1992) suggested that using a primary marker on a vertical surface may help encourage preschoolers to use a tripod grasp, when the child is prompted to place the tips of their fingers on the stripe at the base of the marker. The use of this prompt was not assessed in the current study, and results suggest that children will not use a tripod grasp on a marker when drawing on a vertical surface without a prompt for finger placement. The current study does support the practice of using a piece of chalk/crayon and a vertical surface to facilitate a more mature grasp (Benbow, 1990; Myers, 1992). Thus, a tripod grasp does not seem to be automatically assumed on a vertical surface without manipulating the task or the instructions.

Unlike previous research in this area, the current study not only assessed grasp used with writing tools, but also manipulated the task to see if a more mature grasp was facilitated. Dynamic systems theory does not predict that the organismic subsystems of two-year-old children are unstable enough to move to the attractor state (a mature grasp). However, some of the task adaptations in this study (the crayon paired with the vertical surface and the tip-towards orientation) appear powerful enough to cause some of the children to use a more mature grasp. Orientation was not a powerful constraint as the increase in the maturity of the grasp used was not as large as with the crayon/easel constraint. Other task constraints (the crayon paired with the flat surface and the pencil and marker paired with the easel) were not strong enough to consistently produce a significantly more mature grasp.

Other results that were not addressed by the research hypotheses warranting discussion include gender and orientation effects. The gender effects found in this study are generally consistent with previous research.

Saida and Miyashita (1979) found that three-year-old girls are significantly more advanced in finger posture than three-year-old boys ($p<.005$). Likewise, Schneck and Henderson (1990) found, in children aged 3 years 0 months to 4 years 6 months, boys used more primitive grasps than girls. Finally, Burton and Dancisak (2000) also found a significant gender effect on the maturity of grasp used with overall grasp maturity higher for girls than for boys.

The results of the study also suggest that pencil grasp in two-year-olds can be influenced by how the writing tool is presented to the child. When the pencil or the marker was presented with the tip pointing towards some of the children in the study, they used a more mature grasp than when it was pointed left or right. This phenomenon has not been described in the literature, although Burton and Dancisak noted that some of the three- and four-year-olds in their pilot study were influenced by the orientation of the tool and consequently included four orientations in their study design. Dynamic systems theory can help to explain observations made during the study. The children who held the tool differently depending on the orientation tended to use the grasp that was consistent with the orientation of the tool in comparison to their hand without adjusting their grasp on the tool. Thus, a child using his/her right hand would pick up a marker pointed left with palm down so that the marker tip was pointing radially and place the tip on the paper using a digital pronate or radial cross palmar grasp. If the marker was pointed right, the tendency was to hold it in the palm with the tip pointed ulnarly and place the tip on the paper using a palmar supinate grasp. When the tip was pointed towards the child, the marker was picked up with the finger tips (as it is not parallel to the palm) and flipped up to touch the paper with wrist extension resulting in a grasp with extended fingers. The tip pointed towards position tended to facilitate a neutral or more extended wrist position and the tool being held with the fingers rather than in the palm thus facilitating a more mature grasp. Thus, for some children, the task constraints of the orientation of the marker or pencil were strong enough to facilitate a more mature grasp pattern. As a result, orientation effects should be considered in future studies in this area and in intervention.

The results of the study can also give a picture of grasp use patterns in individual children at the age of two. For example, none of the children in the study used the same grasp for all 14 trials. This would seem to be mostly due to children this age being very variable in the grasps they use. It may also be partly due to the influence of the orientation on some children (i.e. a digital pronate grasp was more often seen when the tool pointed left for right handed children than the other two orientations). However, the task constraints of the crayon on the easel, although producing a more mature grasp overall, did not have that much influence over the variability in the individual child. Only 4 children in the study used the same grasp pattern for all of the pencil and marker trials, changing grasps only with the presentation of the crayon. Thus, very few of these two-year-old children would seem to have a specific behavior pattern or attractor state for grasp.

There are a number of limitations inherent in this study pointing towards avenues for future research. The nature of the sample limits the generalizability of the results. For example, children who were born pre-term, who had health concerns at birth, or whose parents had any developmental or health concerns at 9 months of age were excluded from the sample at the time of recruitment. Thus, the results could not be generalized to these populations. As well, children whose parents spoke a language to them other than English were not included. The average annual income level of the families in the study was relatively high ($40,000 Canadian or higher); although the average grasp used by the children in the study did not correlate with annual income (r=-.13, p>.25). The education level of parent in the sample was also very high but no significant correlations were found between the average grasp used and maternal educational level, maternal years of education, paternal educational level or paternal years of education (each p>.25). As well, although the age homogeneity of the sample is an advantage in that it eliminates age differences as a nuisance variable from the analysis of the hypothesis, a corresponding disadvantage is that the results are limited to this narrow age range. Thus,

future studies of this kind could involve a more representative sample, including children with disabilities and a larger age range.

Comparisons of all of the writing tools available to young children were beyond the scope of this study. However, having a thicker piece of crayon (i.e., a primary crayon) to compare with the regular piece of crayon may have helped determine if tool width would make a difference when combined with tool length and surface angle. As well, the presentation of the tools was not completely consistent due to the use of the easel. The tools presented on the table were placed in front of the child to avoid biasing handedness but had to be placed to one side for the easel in order for the easel to be close enough to the child. However, there was no significant difference in handedness between the table ($\underline{M}$= 79.8%) and the easel ($\underline{M}$ = 78.2%). Thus the presentation of the tools to one side during the easel trials did not appear to influence the hand used. Future studies could compare various widths of small pieces of crayons to further investigate the relationship between length and width of writing tools. This would also allow the presentation of the tool to be the same on the horizontal and vertical surfaces, eliminating the possibility of influencing handedness.

There are also limitations to the measurement of grasp patterns. The trials were short and may not necessarily have reflected how the child normally approaches writing tools. As well, the easel may have been an unfamiliar surface and thus may have altered the child's approach. Finally, it was necessary to make some modifications to the scoring system to accommodate the easel trials. Future studies looking a writing tool length should consider the necessity of these modifications. Perhaps a comparison between this scoring system and a more observational method (such as the observation list used by Blote, Zielstra and Zoetewey (1987) where each position and movement is described in detail rather than categorized as a specific grasp pattern), may provide a more clear description of the grasps used with the crayon trials.

Overall, the study has looked both at the grasp use in drawing environments common to two-year-olds and the effects of imposing task

constraints on the grasp used by two-year-olds. Changes were made within children rather than between children so each acted as his or her own control. The environment was not changed between children, remaining as described in the methods section. Thus, manipulation occurred only in the task consisting of tool length and width, surface angle and tool orientation. Results do not indicate that children this age are ready for a mature grasp (i.e. the organismic subsytems are not sufficient to support a mature grasp alone as they would be in an adult). However, the task constraints of the crayon and the marker are strong enough to facilitate a more mature grasp,

Implications for Practice

This study addresses a number of important practice issues for occupational therapists. First, it provides empirical evidence for the use of short tools with vertical surfaces to encourage mature grasp use, supporting an intervention already in practice (Myers, 1992). However, the study does not provide evidence that the exclusive use of these task constraints will develop a more mature grasp across writing tools earlier than children who use a variety of tools and surfaces. A longitudinal study would be necessary to support the long-term effects of such task constraints.

The study also suggests that a primary marker on a vertical surface will not encourage preschoolers to use a tripod grasp without a prompt for finger placement. Thus, it should be used only in a situation where the child is being monitored and prompted.

While this study may provide some recommendations of the best tools and surfaces to use with young children, it may also have implications for the administration or development of assessment tools that include pencil grasp with regards to the presentation of the writing tools. Therapists should be aware when assessing pencil grasp that some children may use a more mature grasp if the tool tip is pointed towards them. As well, developers of standardized tests should include orientation as part of the administration instructions for grasp assessment.

Another application for practice is the increased information about pencil grasp patterns in two-year-olds. The study confirms the use of the digital pronate grasp as a common pencil grasp in two-year-olds. It also indicates that the grasp with extended fingers is common as well, though this grasp is not addressed in a commonly used preschool fine motor assessment (Folio & Fewell, 2000). This study also shows how variable grasp use is in children of this age, as it is influenced by tool length, surface angle and tool presentation. Thus, developers of standardized tests should also clearly specify the writing tool and surface to be used during any grasp assessment.

Finally, the application of dynamic systems theory provides a new clinical perspective on the assessment and treatment of pencil grasp. Darrah and Bartlett (1995) suggested that therapists need to identify the constraints on the child's behavior (organismic, environmental or task) preventing new behavior patterns, and manipulate these constraints to influence behavior change. This approach may help identify which children require intervention and when the intervention would be most effective (i.e., how stable is the attractor state). As well, Burton and Davis (1992) suggested that changing the constraints of the task to evoke the desired change in the behavior pattern could provide insight into programming strategies.

The limitations to the clinical application of the results of this study include the use of a typically developing sample. Applying the results to children with fine motor delays means assuming that their skills and patterns of development are similar to a child of a younger age. This may not always be the case. As well, when applying the results to children as young as two years of age, parents, teachers and other involved adults may be reluctant to use small pieces of crayon. There is a safety issue related to choking that would apply to young children. As well, small pieces of crayons are often regarded as less desirable by the child than whole crayons as they are broken.

In conclusion, the results of this study provide important empirical evidence to help drive clinical practice. The support for the hypotheses that children will use a more mature grasp with a piece of crayon than a pencil and

that they will use a more mature grasp with the crayon on a vertical surface compared to a flat surface suggests that therapists should continue to recommend this technique as a method of facilitating a more mature grasp. The lack of significant differences in grasp between the marker and the pencil on both surfaces suggest that these tools, even paired with a vertical surface, do not provide the task adaptation needed to influence grasp use in children at age two.

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Appendix A

Information Letter

Title of Project: Pencil Grasp Development

Investigators: Janet Yakimishyn, Graduate Student
Work affiliation: Edmonton Public Schools
Phone Number: 988-8093

Joyce Magill-Evans, Ph.D.
Graduate Supervisor, Dept. of Occupational Therapy
492-0402

Purpose
To study the affect of different writing tools and surfaces on pencil grasp in very young children.

Background
Many drawing tools intended for young children are thicker than ordinary pencils. Thick tools may not encourage a mature pencil grasp. Also, some sources suggest that a surface such as an easel is better for younger children to draw on than a tabletop. The findings of this study may help influence the types of drawing tools available for young children. Treatment of children who have fine motor difficulties often involves the use of modified drawing tools and surfaces. The findings of this study may help to advance treatment of children who have fine motor problems.

Procedures
Children who are part of the Baby Study will be asked to participate in this study. This study will take place at Corbett Hall immediately after the 23-month assessment for the Baby Study. The assessment will be brief (no more than 10 minutes). Your child will draw or mark on paper using three different writing tools. Your child will draw on a flat surface and on an easel. Your child's pencil grasp will be video taped so it can be carefully observed later.

Educational Use of Video Tapes
We would like to use some of the videotapes to train occupational therapy students at the University of Alberta. If you agree, your child's videotape would be used but your child would not be identified. You may refuse to allow your child's tape to be used in this way but still participate in the study. You will need to clearly indicate your agreement on the consent form to release the tape for this purpose.

Risks and Benefits
There are no known risks to you or your child by taking part in this study. The cost of parking is covered by the Baby Study. One benefit to you is that you will learn more about your child's ability to use different drawing tools. The results of the study may help therapists working with young children.

Confidentiality
All the information collected about you, your child or your family during this study is confidential except when professional codes of ethics and/or legislation require

reporting. The videotapes and written materials will be stored in a secure location for seven years. Only the investigators will have access to this information. No information that could identify you, your child or your family will be published.

Freedom to Withdraw
You are free to refuse to take part in this study. You are free to refuse to answer any questions. If you decide to take part, you are free to withdraw at any time. Your participation in this project is not required because of your involvement with the Baby Study. This study is not directly part of the Baby Study. If you choose not to participate, your participation or standing in the Baby Study will **not** be affected.

Contacts: You will be given a copy of this information letter and consent form. If you have any further questions about the study please call Janet Yakimishyn at 988-8093.

If you have any concerns with any aspect of this study, please contact Dr. Sharon Warren, Chair of the Health Research Ethics Board at 492-7856

Thank you for considering taking part in this study

Appendix B

Study Participation Consent Form
Title of Project: Pencil Grasp Development

Investigators: Janet Yakimishyn, Graduate Student
Work affiliation: Edmonton Public Schools
Phone Number: 988-8093

Joyce Magill-Evans, Ph.D.
Graduate Supervisor, Dept. of Occupational Therapy
492-0402

1. Do you understand that you and your child have been asked to be in a research study?	Yes No
2. Do you understand that participation in this study is not a requirement of your participation in the baby study?	Yes No
3. Have you read and received a copy of the attached information sheet?	Yes No
4. Do you understand the benefits and risks involved in taking part in this study?	Yes No
5. Have you had an opportunity to ask questions and discuss this study?	Yes No
6. Do you understand that you are free to refuse to participate or withdraw from the study at any time? You do not have to give a reason and it will not affect your child's or your family's care.	Yes No
7. Has the issue of confidentiality been explained to you? Do you understand who will have access to you and your child's information?	Yes No
8. Do you understand that you do not have to allow your child's videotape to be used as an educational tool to participate in this study?	Yes No

I agree to take part in this study.

_____ _____ _____
Signature of Research Participant Date Witness

_____ _____
Printed Name Printed Name

I believe that the person signing this form understands what is involved in the study and voluntarily agrees to participate.

_____ _____
Signature of Investigator or Designee Date

Appendix C

Educational Use of Video Tapes

We would like to ask your permission to allow us to use your child's videotape to train occupational therapy students at the University of Alberta. The tapes would provide the students with an opportunity to learn about the pencil grasp development of a normally developing child. If you agree, your child's videotape would be used but your child would not be identified. You may refuse to allow your child's tape to be used in this way but still participate in the study. You will need to clearly indicate your agreement on below to release the tape for this purpose.

I agree to allow my child's tape to be used for educational purposes. Yes No

_____	_____	_____
Signature of Research Participant	Date	Witness

_____	_____
Printed Name	Printed Name

I believe that the person signing this form understands what is involved in the educational use of their child's videotape and voluntarily agrees gives permission for it's educational use.

_____	_____
Signature of Investigator or Designee	Date

Appendix D

Script

Parent(s) and child will be greeted and the consent form will be signed. The investigator or designee will ask the parent(s) about the child's drawing experience and handedness and record the information on the tracking sheet. The family will then be taken into the testing room. The horizontal surface will be ready with two video camera paused. A sheet of paper will be taped to each surface. The child will be positioned in the chair and the video cameras turned on. The marker and the colored pencil will be placed on the table in front of the child parallel to the table edge; first pointing right and then pointing left. The pencil or marker will then be presented pointing towards the child. The crayon will be presented only once. The order of the three tools will vary from child to child. With each presentation, the child will be invited to draw on the paper provided. The child will be encouraged to draw for 15 seconds or until finished with the tool and then persuaded to try the next writing tool. When all three tools have been used with the first surface, the second surface will be presented. The child will be given the three writing tools in the same order.

Appendix E

Scoring Criteria

Score	Grasp	Definition
1	Radial cross palmar grasp	Pencil across palm projecting radially, hand fisted, forearm in full pronation, full arm movement (Morrison, 1978, cited in Schneck & Henderson, 1990)
2	Palmar supinate grasp	Pencil across palm projecting ulnarly, hand fisted, slight wrist flexion and supination, full arm movement (Erhardt, 1982)
2	Interdigital grasp (variation 1)	Fingers fisted into palm, pencil across palm and projecting ulnarly from between the index and middle fingers. Movement mostly in metacarpophalangeal and proximal interphalangeal joints of the fingers and at the wrist. Forearm may be resting on table. (Tseng, 1998)
2	Interdigital grasp (variation 2)	Fingers fisted into palm, pencil across palm and projecting ulnarly from between middle and ring fingers. (Tseng, 1998)
2	Interdigital grasp (variation 3)	Fingers fisted into palm, pencil across palm and projecting ulnarly from between ring and little fingers. (Tseng, 1998)
2	Digital pronate grasp, only index finger extended	Pencil in palmar grasp with index finger extended along pencil toward tip. The arm is not resting on the table and full arm movement occurs.
3	Brush grasp	Pencil held in fingers with eraser end of pencil against palm, hand is pronated with both wrist and whole arm movement. Forearm not resting on table. (Schneck & Henderson, 1990)
3	Grasp with extended fingers	Pencil held in fingers, wrist straight with pronation and slight ulnar deviation, forearm moves as unit. (Schneck & Henderson, 1990)
4	Cross thumb grasp	Fingers loosely fisted in to palm, pencil held against index finger with thumb crossed over pencil toward index finger, finger and wrist movement present, forearm rests on table. (Gesell, 1940, cited in Schneck & Henderson, 1990)

4	Static tripod grasp	Pencil stabilized against radial side of middle finger by thumb pulp with index pulp on top of pencil shaft, thumb is stabilized in full opposition, slight wrist extension and hand moves as unit. Pencil rests in open thumb web space, forearm rests on table (Rosenbloom & Horton, 1971, cited in Schneck & Henderson, 1990)
4	Four finger grasp	Pencil held with four fingers in opposition, wrist and finger movement, forearm positioned on table (Schneck & Henderson, 1990)
5	Lateral tripod grasp	Pencil stabilized against radial side of middle finger with index finger on top of pencil shaft, thumb adducted and braced over or under anywhere along lateral border of index finger, wrist slightly extended, ring and little fingers move with tripod and wrist on tall and horizontal strokes, forearm rests on table (Scheck, 1987, cited in Schneck & Henderson, 1990)
5	Dynamic tripod grasp	Pencil stabilized against radial side of middle finger by thumb pulp with index pulp on top of pencil shaft, thumb is stabilized if full opposition, slight wrist extension, ring and little fingers are flexed to stabilize metacarpal arch and middle finger, localized movement of tripod and wrist movements on tall and horizontal strokes, forearm rests on table. (Rosenbloom & Horton, 1971, cited in Schneck & Henderson, 1990)
5	Quadrupod grasp	Identical to dynamic tripod grasp except pencil is stabilized against radial side of ring finger by the thumb pulp with index and middle finger pulps on the pencil shaft, and the thumb is stabilized in full opposition. Uses intrinsic muscle movements in a coordinated manner with forearms resting on table (Tseng, 1998)

Appendix F

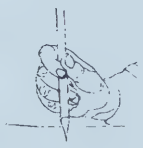
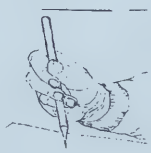
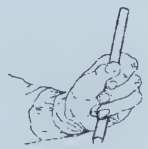
Other grasps described in Tseng, 1998

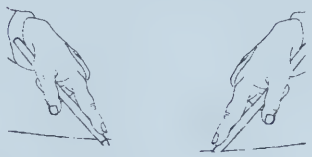
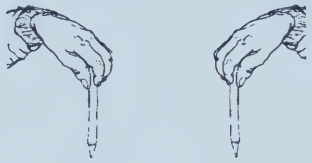
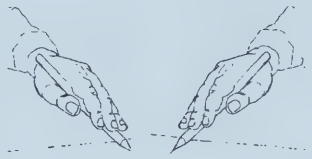
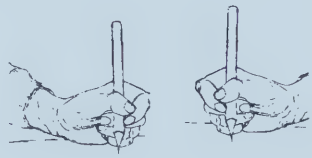
1. Interdigital grasp (variation 1) – fingers fisted into palm, pencil across palm and projecting ulnarly from between the index and middle fingers. Movement mostly in metacarpophalangeal and proximal interphalangeal joints of the fingers and at the wrist. Forearm may be resting on table. (Tseng, 1998)
2. Interdigital grasp (variation 2) – Fingers fisted into palm, pencil across palm and projecting ulnarly from between middle and ring fingers. (Tseng, 1998)
3. Interdigital grasp (variation 3) – Fingers fisted into palm, pencil across palm and projecting ulnarly from between ring and little fingers. (Tseng, 1998)
4. Quadrupod grasp – identical to dynamic tripod grasp except pencil is stabilized against radial side of ring finger by the thumb pulp with index and middle finger pulps on the pencil shaft, and the thumb is stabilized in full opposition. Uses intrinsic muscle movements in a coordinated manner with forearms resting on table (Tseng, 1998)

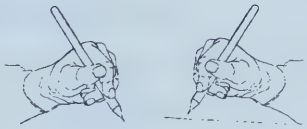
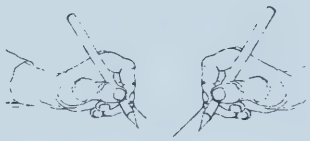
Tseng's categories reported in developmental order: Radial cross palmar grasp, palmar supinate grasp, interdigital grasp (variation 1), interdigital grasp (variation 2), interdigital grasp (variation 3), digital pronate grasp, only index finger extended, brush grasp, grasp with extended fingers, cross thumb grasp, static tripod grasp, four finger grasp, lateral tripod grasp, dynamic tripod grasp and quadrupod grasp.

Appendix G

Score Sheet for the Pencil Grasp Study

Score	Grasp	Definition	Illustration Left	Illustration Right
1	Radial cross palmar grasp	Pencil across palm projecting radially, hand fisted, forearm in full pronation, full arm movement (Morrison, 1978, cited in Schneck & Henderson, 1990)		
2	Palmar supinate grasp	Pencil across palm projecting ulnarly, hand fisted, slight wrist flexion and supination, full arm movement (Erhardt, 1982)		
2	Interdigital grasp (variation 1)	Fingers fisted into palm, pencil across palm and projecting ulnarly from between the index and middle fingers. Movement mostly in metacarpophalangeal and proximal interphalangeal joints of the fingers and at the wrist. (Tseng, 1998)		
2	Interdigital grasp (variation 2)	Fingers fisted into palm, pencil across palm and projecting ulnarly from between middle and ring fingers. (Tseng, 1998)		
2	Interdigital grasp (variation 3)	Fingers fisted into palm, pencil across palm and projecting ulnarly from between ring and little fingers. (Tseng, 1998)		

2	Digital pronate grasp, only index finger extended	Pencil in palmar grasp with index finger extended along pencil toward tip. The arm is not resting on the table and full arm movement occurs.	
3	Brush grasp	Pencil held in fingers with eraser end of pencil against palm, hand is pronated with both wrist and whole arm movement. Forearm not resting on table. (Schneck & Henderson, 1990)	
3	Grasp with extended fingers	Pencil held in fingers, wrist straight with pronation and slight ulnar deviation, forearm moves as unit. (Schneck & Henderson, 1990)	
4	Cross thumb grasp	Fingers loosely fisted in to palm, pencil held against index finger with thumb crossed over pencil toward index finger, finger and wrist movement present. (Gesell, 1940, cited in Schneck & Henderson, 1990)	
4	Static tripod grasp	Pencil stabilized against radial side of middle finger by thumb pulp with index pulp on top of pencil shaft, thumb is stabilized in full opposition, slight wrist extension and hand moves as unit. (Rosenbloom & Horton, 1971, cited in Schneck & Henderson, 1990)	
4	Four finger grasp	Pencil held with four fingers in opposition, wrist and finger movement (Schneck & Henderson, 1990)	

5	Lateral tripod grasp	Pencil stabilized against radial side of middle finger with index finger on top of pencil shaft, thumb adducted and braced over or under anywhere along lateral border of index finger, wrist slightly extended, ring and little fingers move with tripod and wrist on tall and horizontal strokes, forearm rests on table (Scheck, 1987, cited in Schneck & Henderson, 1990)	
5	Dynamic tripod grasp	Pencil stabilized against radial side of middle finger by thumb pulp with index pulp on top of pencil shaft, thumb is stabilized if full opposition, slight wrist extension, ring and little fingers are flexed to stabilize metacarpal arch and middle finger, localized movement of tripod and wrist movements on tall and horizontal strokes, forearm rests on table. (Rosenbloom & Horton, 1971, cited in Schneck & Henderson, 1990)	
5	Quadrupod grasp	Identical to dynamic tripod grasp except pencil is stabilized against radial side of ring finger by the thumb pulp with index and middle finger pulps on the pencil shaft, and the thumb is stabilized in full opposition. Uses intrinsic muscle movements in a coordinated manner with forearms resting on table (Tseng, 1998)	

Appendix H

Table 7 Interrater Reliability Grasp Label Disagreement

Presentation of Tool/Surface/Orientation	Number of Disagreements	Presentation of Tool/Surface Totals
Marker Table Right	2	8
Marker Table Towards	2	
Marker Table Left	4	
Pencil Table Right	2	5
Pencil Table Towards	1	
Pencil Table Left	2	
Crayon Table	6	6
Marker Easel Right	1	2
Marker Easel Towards	0	
Marker Easel Left	1	
Pencil Easel Right	0	7
Pencil Easel Towards	4	
Pencil Easel Left	3	
Crayon Easel	2	2

Appendix I

Introductory Letter

Dear Parent:

An occupational therapy graduate student is studying the development of young children's pencil grasp. She will be studying how children hold different writing tools when drawing/scribbling on a table or an easel. We are writing to you for permission to release your name and phone number to her so that she can contact you about her study. Enclosed is a letter describing the study. You do not have to agree to participate in this study. Choosing not to participate in this study will not affect your participation in the Baby Study. The principal investigator of the second study will not have access to your name or phone number until you give permission for that information to be released.

If you wish to participate in the Pencil Grasp Study or would like more information, please indicate this on the enclosed card and return it in the self addressed stamped envelop. The principal investigator of the Pencil Grasp Study will then contact you and explain the study to you. If you agree to participate, an appointment will be made immediately following your child's assessment at Corbett Hall. Please note that the assessment generally takes only 10-15 minutes so your child should not be too tired to participate in the Pencil Grasp Study, which takes no more than 10 minutes

Thank you for your interest.

Sincerely,

Johanna Darrah, Ph.D.

Appendix J

Tracking Sheet Order 1

Child's Name _____

Family Number _____ Tape number _____

Does your child draw/color at home? Yes No

Does your child enjoy drawing/coloring? Yes No

About how often does your child color in a week? _____

About how long will your child draw/color at one time? _____

What does he/she draw/color with? _____

_____

1. Horizontal surface
   a. Marker
   b. Pencil
   c. Crayon
2. Vertical Surface
   a. Marker
   b. Pencil
   c. Crayon